



Impedance

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Purpose:

Examine the frequency dependent behavior of impedance.

Equipment Required:

- 1 - Agilent 34401A Digital Multimeter
- 1 - Agilent 33120A Waveform Generator
- 1 - Agilent 54622A Deep Memory Oscilloscope or Agilent 54600B Oscilloscope
- 1 - Agilent 4263B RCL Meter (can be shared)
- 1 - Protoboard
- 1 - 1-kΩ Resistor
- 1 - 0.1-μF Capacitor
- 1 - 100-mH Inductor

Prelab:

Read Sections 13-1 through 13-2 in the text.

The s-domain impedance can be expressed in the phasor domain by substituting $j\omega$ for s . In the sinusoidal steady state, the impedance of the three passive components vary with frequency according to the following relationships:

$$Z_R = R \tag{2}$$

$$Z_L = j\omega L \tag{3}$$

$$Z_C = \frac{1}{j\omega C} \tag{1}$$

In this laboratory exercise you will verify these element constraints by comparing the impedance calculated from the relationships above, to the magnitude of the impedance calculated from the measured voltage across and the current through the elements at different frequencies.

Prepare a table in your journal with thirteen columns, labeled Freq, v_R , i_R , $|Z_{Rmeas}|$, $|Z_{Rtheo}|$, v_C , i_C , $|Z_{Cmeas}|$, $|Z_{Ctheo}|$, v_L , i_L , $|Z_{Lmeas}|$ and $|Z_{Ltheo}|$. Fill in the first column, starting at a frequency of 10 Hz. Write in the remaining frequencies in standard logarithmic frequency steps (1, 2, 5, 10) up to 100 kHz. The *meas* subscript indicates the value is computed from the measured values of the voltage and current. The *theo* subscript indicates the impedance is calculated from the appropriate equation, Eq. 1, 2 or 3, depending on the element. The vertical bars serve as a reminder that these measurements represent the magnitude of the impedance, without regard to the phase angle between the current and voltage.



Procedure

1. Prepare the circuit

- a. Use the RCL meter to measure and record the value of each of the elements. Measure and record the parasitic resistance R_p of the inductor.

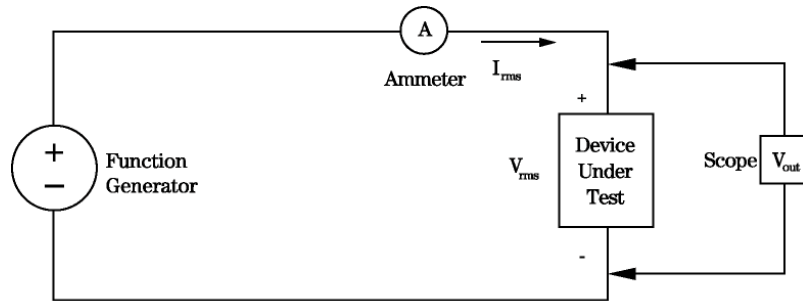


Figure 1

- b. Build the circuit of Fig. 1. Put the 1-k Ω resistor in the circuit location indicated by the box labeled Device Under Test.
- c. Set the waveform generator to produce a 10 Hz sine wave. The amplitude of the signal produced by the waveform generator should be set so that convenient scales on the ammeter and the oscilloscope can be used. Set the DMM to measure I_{rms} on the most sensitive current range.

Start with the waveform generator output amplitude turned down all the way. Slowly increase the amplitude on the waveform generator until the ammeter is indicating nearly full scale on this range.

2. Measure the impedances

As the frequency of the signal from the waveform generator is changed, the impedance equations for the inductor and capacitor (Eq. 2 and 3) predict that the current through and the voltage across these two elements will also change. Freely adjust the ranges on the ammeter and the oscilloscope, and the amplitude of the signal from the waveform generator so that signal levels are readily measured by the ammeter and the oscilloscope.

- a. Measure and record the current, I_{rms} and the voltage V_{pp} . Adjust the input frequency to the next data point, then re-measure the current and voltage. Continue in this manner until the resistor v-i data is complete through 100 kHz.
- b. Remove the resistor from the circuit, and insert the capacitor in its place. Fill in the data columns for the capacitor current and voltage.
- c. Replace the capacitor with the inductor. Fill in the data columns for the inductor current and voltage.

Conclusion:

Prepare the data

The current and voltage data acquired above are in different units. The ammeter indicates current in rms (root mean square) — the voltage was measured in V_{pp} . Before computing the magnitude of the element impedance, the V_{pp} data will need to be converted to V_{rms} , using the relationship shown in Eq. 4.



$$V_{rms} = \frac{V_{pp}}{2\sqrt{2}} \quad (4)$$

Enter the numbers from your data table into a spreadsheet program. Write equations for the columns in your data table that are currently blank. Print out the complete spreadsheet and tape it into your lab journal.

Plot the data

On one graph plot both the theoretical and the empirical (measured) impedance for all three elements. Both axes should be logarithmic, with the frequency on the horizontal axis and the impedances on the vertical axis. To help identify the curves, set up the line format so that the theoretical curves are of one line type, or color, and the empirical curves are of a different line type or color. Print out the graph. Clearly label each curve and tape the sheet into your journal.

In procedure 1a you measured the parasitic resistance of the inductor. At what frequencies does this resistance create a significant difference between $|Z_{L_{meas}}|$ and $|Z_{L_{theo}}|$? Can the calculated inductor impedance $|Z_{L_{theo}}|$ be corrected to eliminate the separation between the plots of $|Z_{L_{meas}}|$ and $|Z_{L_{theo}}|$?

At high frequencies, it is likely that the empirical impedance of the inductor will deviate from the theoretical impedance. Suggest a reason for this behavior. Hint: scan through appendix A in the text.

* Roland E. Thomas and Albert J. Rosa, The Analysis and Design of Linear Circuits, Prentice Hall, (New Jersey, 1994)